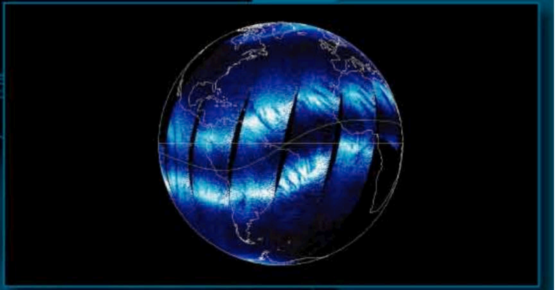
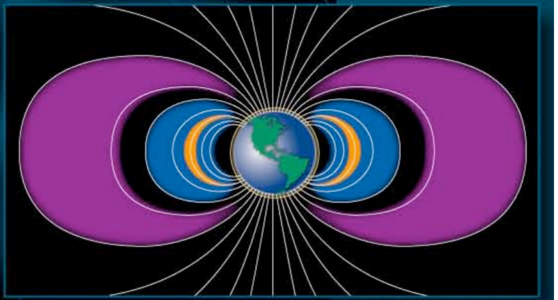
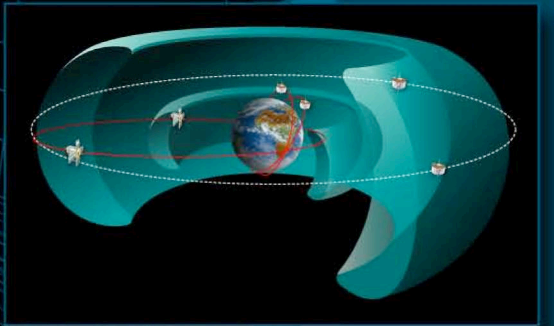
Overview of Concept Spacecraft







Announcement of Opportunity for the
Radiation Belt Storm Probes
and Geospace-Related Missions of Opportunity

Dana Brewer
LWS Program Executive

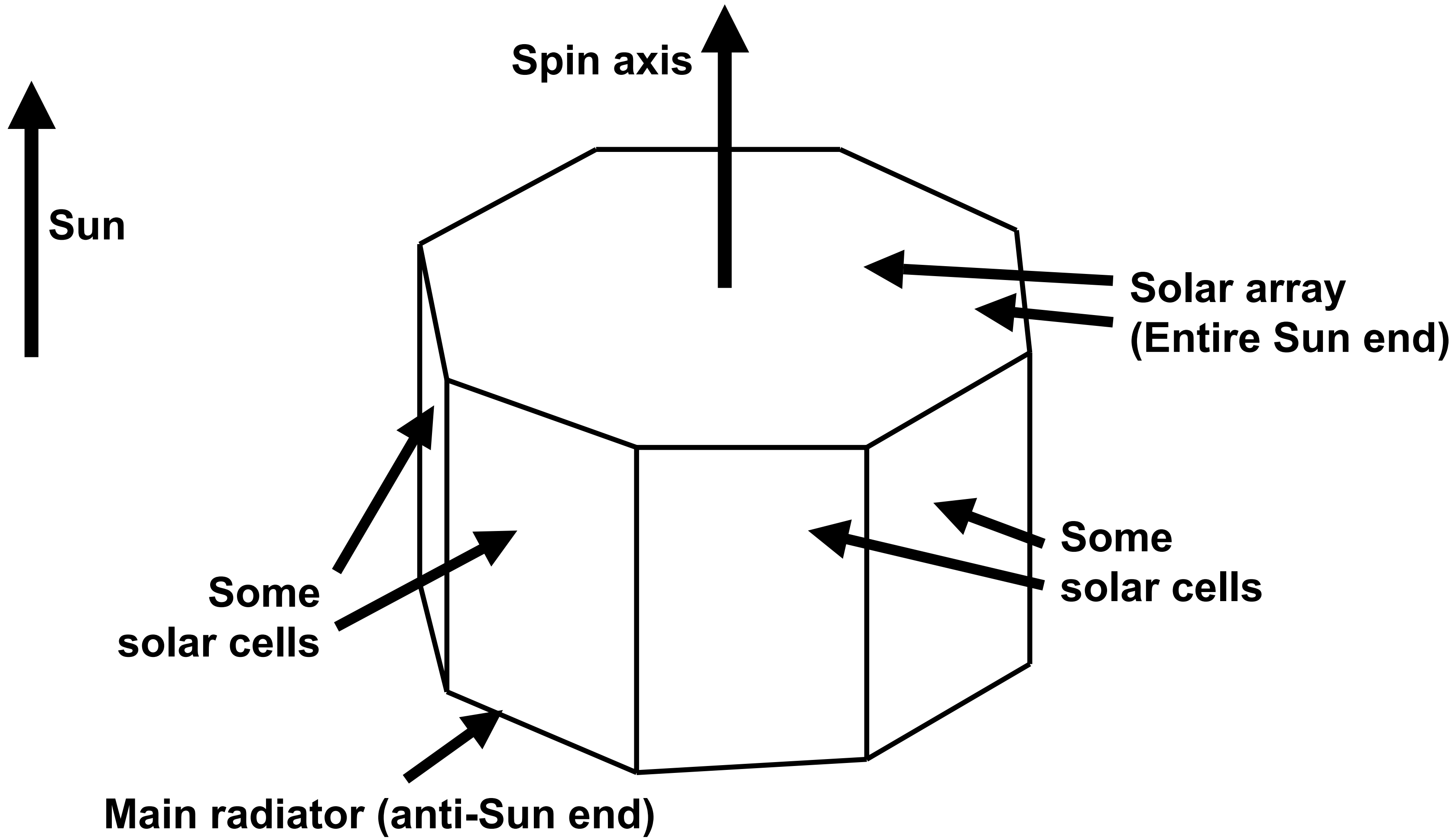
Presentation Outline and Caveat

This presentation will describe the following:

- A notional spacecraft concept based upon a candidate set of measurements recommended by the Geospace Mission Definition Team as having highest priority
- Planning schedule for the Radiation Belt Storm Probe Mission

- The notional spacecraft concept is based upon a sample instrument complement from the Geospace Mission Definition Team Report that is expected to be able to meet both the mission science objectives and reflects the resource envelope that NASA expects to be able to select.
- It is emphasized that this Announcement of Opportunity solicits complete science investigations, of which the candidate measurements, concept instruments, and notional spacecraft may be only one means for obtaining the necessary data.
- The spacecraft concept will be modified to accommodate the selected science investigations.

Notional Concept: Two Identical Spin-Stabilized Spacecraft Launched Together on Delta 2925



Spacecraft Attitude Control and Command & Data Handling

- **Attitude knowledge and spin information**
  - Provided by the spacecraft's Earth and Sun sensors
    - **This sensor information will be stored in the spacecraft housekeeping data and down-linked during ground contact periods**
  - Knowledge to within 1-degree (3-sigma) accuracy
  - Spin information to within 2 degrees (3-sigma) accuracy
- **Command and data handling controls all observatory operations:**
  - Routes communications between the ground and instruments using Consultative Committee for Space Data Systems (CCSDS) command and telemetry-formatted data packets
  - Forwards the up-linked packets to the instruments
  - Provides a time reference data packet to instruments
  - Collects, stores, and forwards instrument telemetry packets to the ground

Spacecraft Thermal Control and Communications

- **Thermal control: passive by conductively coupling to spacecraft structure**
  - The internal structure and surfaces will be maintained between -20 and +40^{O}C
  - Temperature stability will nominally be ±5^{O}C over an orbit
- **Communications:**
  - Provides a bi-directional link compatible with commercial ground network assets
  - Sized to downlink science and spacecraft housekeeping data once per day
  - Uplink command rates vary between 100 bps and 2 kbps and depend upon:
    - **Proximity of the spacecraft to Earth**
    - **Angular aspect of the ground station**
    - **Ground station characteristics**

Spacecraft Power and Propulsion

- **Power subsystem provides primary power distribution, power switch control, and power fault isolation**
  – Primary power is unregulated between 21 and 35 Volts DC
  – At least one switched primary power service will be provided to each instrument for operational power
  – A battery provides all power during eclipse periods
- **Propulsion:**
  – Provides spin control using monopropellant hydrazine
    - **Spin control: Within 15 degrees (half-cone angle) of the solar vector**
    - **Spin rate: Approximately 5 revolutions per minute**

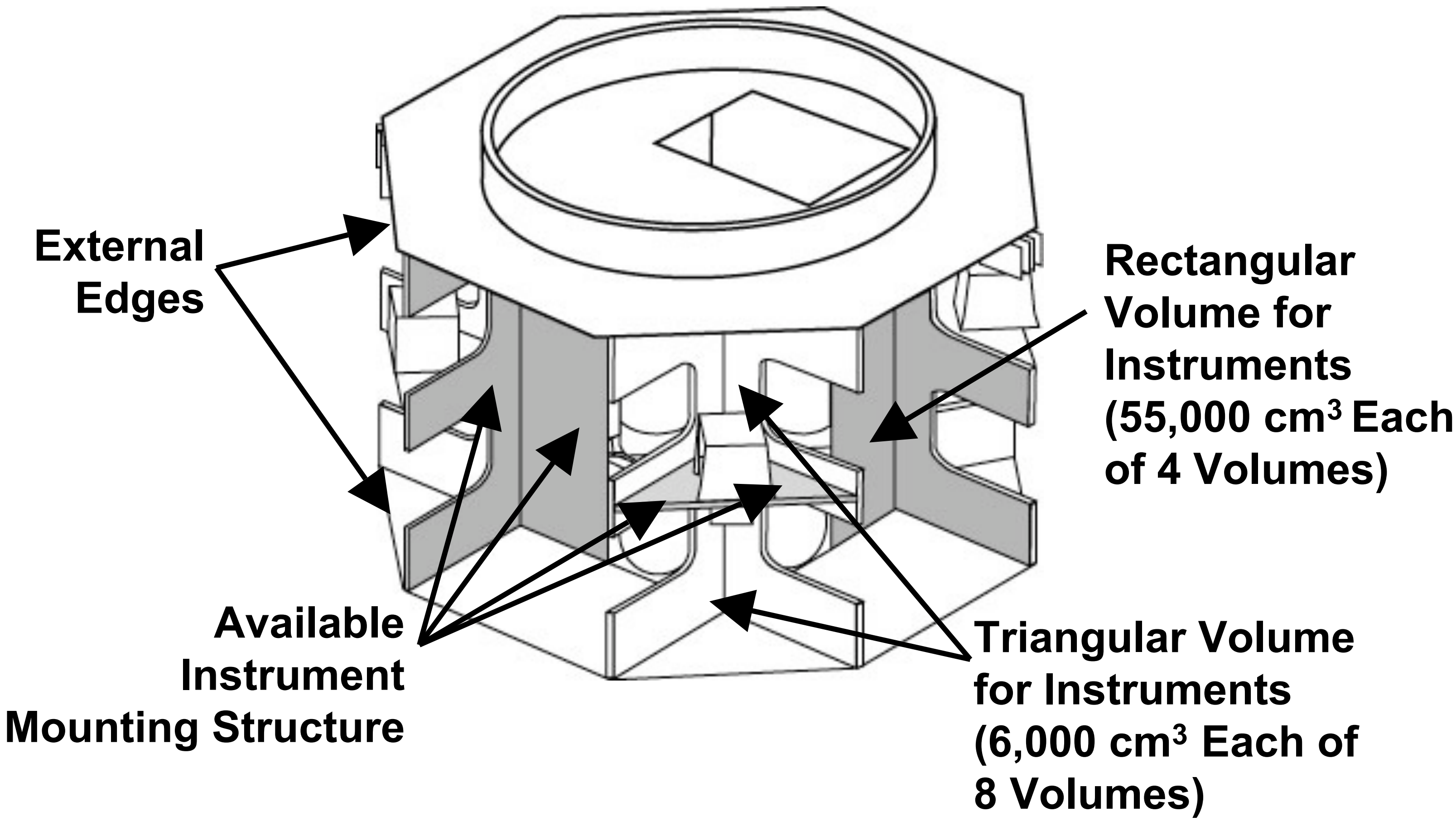
Maximum Payload Resources Available from Each Spacecraft

Resource	Maximum Available*
Mass (kg)	67
Operational Power (W)	27
Peak Power (W)	40
Survival Power (w)	10
Orbit Average Data Rate (kbps) **	9.4
Burst Data Rate (kbps)	64

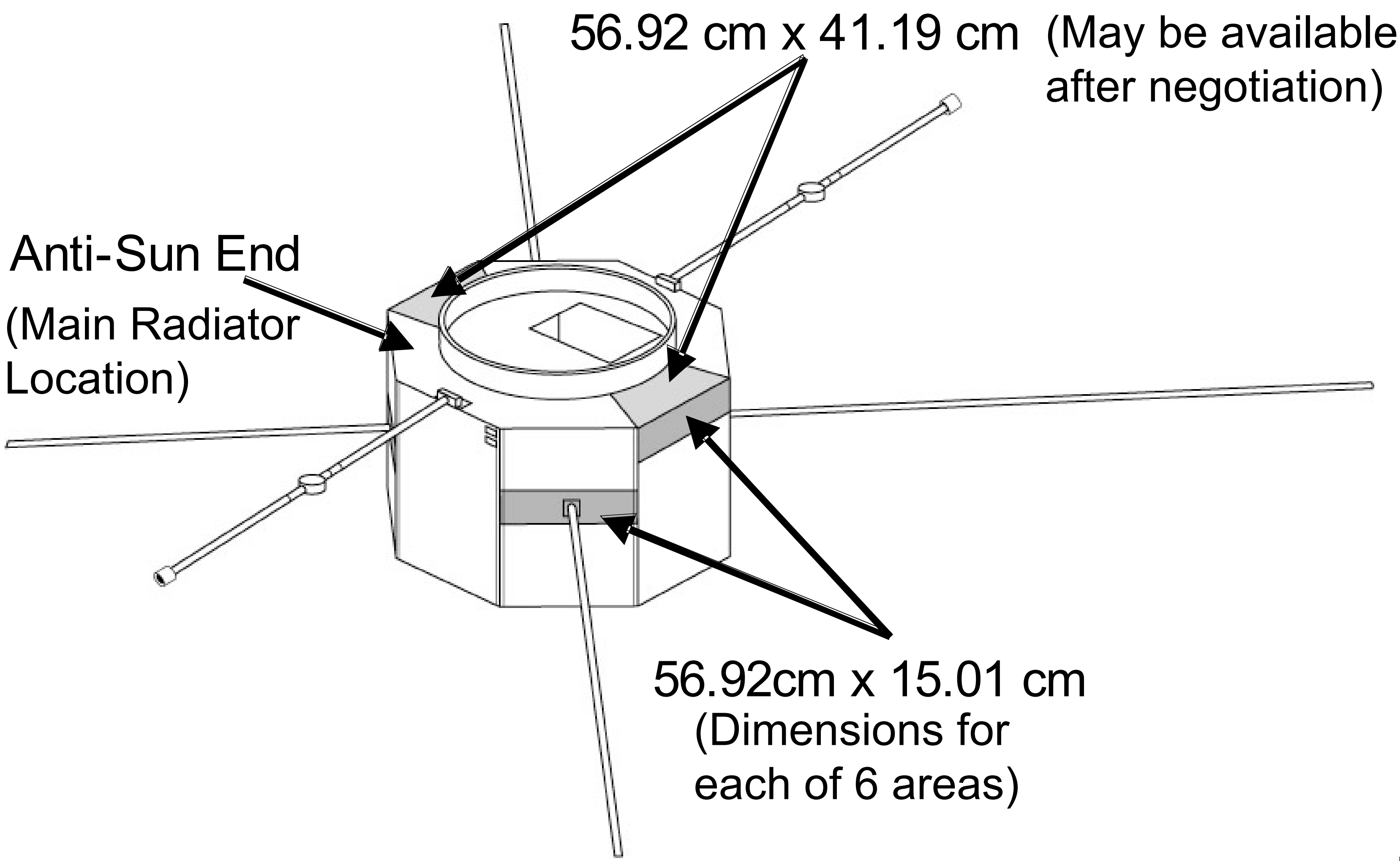
* Inclusive of all margins and reserves
** Includes Consultative Committee for Space Data Systems (CCSDS) Packet Headers

Burst rate implementation will be based on the mission science requirements determined through this solicitation. The burst rate given in the AO is intended to represent the maximum data collection rate that could be sustained over about 5% of the orbit.

Notional Concept: Depiction of the Instrument Mounting Structure and Volume in the Spacecraft Interior



Notional Concept: Depiction of Areas (Shaded) on the External Spacecraft Structure Reserved for Instrument Penetration/Mounting



Design Requirements for Instrument-Deployed Appendages

- **Do not hinder spacecraft from maintaining spin balance and stability**
  - Provide asymptotic stability for any fixed length
    - **Bounded stability of antennas is required during deployment**
- **Minimize attitude disturbances due to deployed appendages**
- **Provide dynamic models of instrument appendages in both the stowed and deployed configurations to support the spacecraft system design.**
  - Do not assume that heritage mechanical interfaces can be accommodated without modification

Instrument Design Requirements for Power

- **Interface to the spacecraft on a dedicated primary power interface connector that is isolated from secondary power**
  - The dedicated interface may include operational, survival, and primary power pulse commands
  - Survive without damage over a range of primary power voltages from -2.0 VDC to +40.0 VDC
- **Pre-planned power cycling may be required for extended eclipse periods**
- **Survival power**
  - Operational power may be removed from instruments without notice during anomalous conditions
  - Survival power will be supplied when operational power is removed
    - **Instruments should only require survival power when operational power is removed.**
- **A few power pulse command (nominally +28V pulse) interfaces are available for one-time activations (deployments) or occasional control functions**

Instrument Design Requirements for Thermal Control

- **Provide a thermal control design and thermal control hardware for all proposed instrument components**
  - Internally-mounted components can use passive thermal control by conductively coupling to the spacecraft structure provided that the nominal heat transfer capacity does not exceed 0.06 W/cm^2 of mounting surface
  - Instrument components that are primarily external to the spacecraft surface need to be thermally isolated from the spacecraft and provide their own thermal control
- **Provide a thermal model of all instrument components for integration into an integrated spacecraft thermal mode**
  - Preliminary models are developed in Phase A and refined in Phase B
- **Comply with the *General Environment and Verification Specification (GEVS) for STS and ELV Payloads, Subsystems and Components, Revision A* (available through Appendix C)**

Instrument Design Requirements for Structures, Acoustics, and Attitude Control

Structures:

- **Comply with mechanical and structures requirements for proto-flight components in the General Environment and Verification Specification (GEVS) for STS and ELV Payloads, Subsystems and Components, Revision A.**

Acoustics:

- **Be compatible with the acoustic environment defined for the Delta 2925H expendable launch vehicle**

Attitude Control:

- **Identify requirements for accuracy in alignment knowledge relative to the spacecraft coordinate system in the proposal**
  - Identify plans for using any special reference devices (such as optical cubes)
  - Identify requirements for absolute co-alignment with respect to other instrument components or the spacecraft spin axis

Instrument Design Requirements for Command and Data Handling

- **Communication services between the ground and instruments will be a “bent pipe,” i.e., a relay of data to and from the instrument interface**
  – No instrument data processing, formatting, or compression on the spacecraft
  – Spacecraft will support storage of pre-planned command packets for distribution to instruments at a later time without processing
- **Spacecraft data recorder will temporarily store instrument data**
- **The spacecraft will broadcast a time synchronization message at 1 Hz**
- **Instrument providers need to annotate instrument data with a broadcast time if needed for data analysis**
  – Correlation with Universal Time will not be available in real-time
  – The spacecraft developer will implement one of 3 command and data interfaces with the instruments:
    - **MIL-STD-1553 redundant serial bus**
    - **A pair of synchronous serial data interfaces**
    - **A pair of asynchronous serial data interfaces**

Instrument Design Requirements for Environments

<u>Contamination Control</u>

- **Provide any required doors and mechanisms needed to minimize contamination onto sensitive surfaces**

<u>Electrostatic Controls</u>

- **Minimize electrostatic disturbances in the vicinity of the spacecraft**
- **Maximize use of electrically-conductive external surfaces**

<u>Electromagnetic Compatibility</u>

- **Comply with the EMI/EMC requirements in the *General Environment and Verification Specification (GEVS) for STS and ELV Payloads, Subsystems and Components* (available through Appendix C)**
  – Minimize conducted and radiated emissions in the range from 10 Hz to 10 KHz

<u>Magnetic Cleanliness</u>

- **Minimize residual and induced magnetic fields**
  – The integrated generated DC magnetic field will be $\leq$ 10 nT at 1 meter from any external surface

Mission Operations Concept

- **A single Mission Operations Center (MOC) will coordinate and perform mission operations**
  - It will oversee the control, command, telemetry download distribution, and health and safety monitoring of the spacecraft
  - It will receive instrument commands
  - It will manage the spacecraft and instrument uplink loads
  - It will transmit the unprocessed science data directly to the investigators' Science Operations Centers (SOC)
- **A ground station will receive and process downlink telemetry and deliver the instrument telemetry to the appropriate locations for further processing**
  - Both instrument and spacecraft housekeeping data will be included
- **Each PI provides a science operations capability and a SOC**
  - The SOC will receive data from the MOC, plan scientific observations, generate instrument command timelines, and perform science data analyses
  - The SOC is solely responsible for the health and safety of the PI's instrument
- **Mission operations has 3 phases: launch and early operations; prime operations; and science data distribution**

Details of Mission Operations Concept

- **Early operations (0-30 days after launch):**
  - Establish spacecraft orientation and drift velocity
  - Deploy and check out the spacecraft and instruments
  - Commission instruments and spacecraft for prime mission operations
- **Prime Mission Operations**
  - Staff MOC a few hours per day for five days per week
  - Limit ground contact for command uploads to a few per week
  - Command during weekdays when staff are present
- **Science data distribution**
  - Begins when prime operations begins with minimal delays between data receipt at SOC and data available to community
  - Ends with deep data archiving for 1 year after prime mission operations ends

Planning Schedule for the Radiation Belt Storm Probe (RBSP) Mission

Table 5.4: Planning Schedule for the RBSP Mission

Phase A	March 2006 – March 2007
Initial Confirmation Review	March 2007
Phase B	April 2007 – April 2008
Confirmation Review	April 2008
Phase C/D	May 2008 – February 2011
Flight Instrument Delivery & Integration	January 2010 – December 2010
Launch	February 2011
Phase E	March 2011 – March 2013
Plus one-year final data analysis	March 2013 - March 2014

- **The planning schedule should be the basis for schedules in proposals**
- **Planning notes:**
  - The planning schedule may be revised during Phase A
  - Proposals must clearly identify sufficient reserves (both schedule and financial) to ensure on-time delivery of the instruments